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FEEDING FAT INTO MILK;

OR THE EFFECT OF THE FOOD UPON THE QUALITY AND QUANTITY OF MILK PRODUCED.

RECENT EXPERIMENTAL INQUIRY UPON MILK SECRETION.

By Chas. D. Woods, B. S.

THE PHYSIOLOGY OF MILK SECRETION.

By A. W. Bitting, M. D.

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FEEDING FAT INTO MILK;

Or the effect of the food of the cow upon the quality and quantity of milk produced.

[INTRODUCTION.—No question in practical dairying has been more actively discussed in recent years than that of effects of different kinds and quantities of food upon the quality or richness of the milk of the cow. Can fat be fed into milk? Many cow owners of long experience believe that it can, and they give numerous examples where the richness of milk or the quantity of butter produced has been apparently increased by some special change in feeding or addition of food. And yet the most noted dairy teachers and the experiment-station men and other systematic investigators are practically unanimous on the other side of the question. They agree that although changes of feed may make temporary changes in the fat in milk, the permanent quality of every cow's milk is inherent in the cow herself. A cow bred or born to give rich milk will always give rich milk if she is fairly well fed and treated, with little regard to the kind and character of her food; and if a cow starts out in life by giving milk poor in fat no method of feeding and no kind of food will materially or permanently change the character of her milk.

This is a very important subject, and for the sake of economical management every dairyman should feel satisfied about it. It is a matter of dollars and cents. The simple fat tests now so well known enable the milk of any cow to be easily tested and its richness positively settled. If it is true that better or different feeding will not permanently improve the richness of milk of a cow which gives a low, unsatisfactory test, it is folly to waste feed upon her in attempting the impossible. Owners will be much more willing to dispose of cows proved by test to be giving poor milk, if fully convinced that no treatment will make this milk much better.

It is therefore desirable to place the facts on this live question within the reach of as many owners of dairy cows as possible. Accordingly, two papers upon this subject are herewith republished by permission of their authors. Both present the facts of the case according to the best knowledge of the time, in a fair, clear, and interesting manner. Differing somewhat in method of treatment, they substantially agree, and each supplements the other. Both papers go beyond the relation of food to the quantity and quality of milk, and discuss also the physiology of milk secretion, the physical characteristics of milk, and the effects upon milk production and the milk itself of drugs, nervous excitement, exposure, exercise, fatigue, and other abnormal conditions. Together they treat this general subject of milk secretion comprehensively and in a way which can not fail to be entertaining and instructive to dairymen generally.

HENRY E. ALVORD,
Chief of Dairy Division.

WASHINGTON, D. C., *February, 1902.*]

Dy.—38.

RECENT EXPERIMENTAL INQUIRY UPON MILK SECRETION.

By CHARLES D. WOODS, B. S.,
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To the dairyman all that is of practical importance in milk secretion centers around the quantity and the quality of the milk. Experimental inquiry has been very active along these lines during the past ten or fifteen years, and the chief embarrassment in attempting a summary of what has been undertaken and the results which have been obtained is the abundance and the variety of the data. The station publications are replete with such results, and in the paper which follows the attempt is made to put in a compact and easily understood form the more important conclusions which have been reached and some of the data upon which they rest. Desirable as it would be to insert references as to the authorities quoted, the limits of a popular paper will not for the most part allow of such reference, and for the most part quotation marks are also omitted.

THE UDDER OF THE COW.

The udder of the cow consists of two glands lying horizontally side by side and separated by a layer of tissues which helps to support them. The glands are distinct from each other, as may be noted by examining the under side of the udder, where the furrow separating them will be found. Each gland ordinarily has two teats on its lower side through which the milk may be drawn from that particular gland. Each of the four teats draws the milk from what is usually termed a "quarter" of the udder. The two teats on the same side of the udder are from the same gland. As the glands are distinct from each other, so in a measure are the quarters. For example, it frequently occurs that cows have garget in one quarter while the other teat from the same gland milks freely and appears healthy.

If an udder be dissected it appears somewhat spongy and pinkish, having numerous holes, or canals, much like a sponge. When cut, milk escapes from the incision. Within each teat is a cavity from which the milk is drawn. At the lower end of each teat a small muscle encircles the outlet to prevent the escape of the milk. Each of the glands of the udder is composed of a quantity of structure somewhat resembling a bunch of grapes. That which may be considered to represent the bunch is called the lobe; the lobule corresponds to one grape, and the alveoli are smaller glands or ducts within the lobule. The alveoli are exceedingly small and can be seen only under a microscope of high power.

The actual secretion of the milk goes on in the alveoli. Exactly how the milk is secreted is not known. It is usually supposed that

the process of milk secretion is twofold; that one is a breaking down of the cells in the alveoli which form the fat of the milk, and the remainder of the process is purely a secretive one, much as saliva is formed in salivary glands. The assumption is sometimes made that in the milk glands of the cow there are as many different and more or less independent forces at work as there are constituents of the milk, and that each of these forces provides for the formation of a single constituent of the milk. A theory which seems to have a greater acceptance at the present time is that the milk glands are possessed of forces which are first of all directed to the formation of milk fat, and the other milk constituents (casein, milk sugar, mineral matters, etc.) occur in a sense as by-products.

Bearing upon the above is the well-known fact that as the period of lactation advances there is a marked diminution in the activity of the milk glands, and this affects the secretion of fat proportionately less than that of the other milk constituents. It is also well known that fluctuation in the regular flow of milk during lactation usually more largely affects the secretion of fat, and it is also frequently observed that to a certain extent the milk yield seems to be determined by the relative tendency of the milk glands to secrete fat.

However the milk may be secreted in the alveoli, it seems to be well established that the milk finds its way through channels of the alveoli into the lobules, and from there into the lobes, and thence into the ducts, whence it is conveyed into the milk cistern above the teats.

THE MILK VEINS.

The nervous system of the cow is closely associated with the production of the milk. When the teats are stimulated, either by the hands or the sucking of the calf, the nerves surrounding them become irritated, and through these the nerves of the secreting glands within the udder are excited, causing their contraction and the discharge of their contents. The action of the blood vessels and veins is affected by the activity of the nerves. Ordinarily the greater the capacity of the arteries and veins connected with the udder the larger the milk secretion will be. This shows the importance of securing cows with a strong development of the arteries and veins of the udder and abdomen. An examination of the belly of a good dairy cow reveals thereon, extending from the udder along each side, a milk vein about one-half inch in diameter. The milk veins at the point most distant from the udder pass through what are called the milk wells in the walls of the abdomen. These openings through which the veins pass should be of good size, so as to permit a strong flow of blood through them. As a rule, the greater the milk-secreting power of the cow the larger and more twisted of outline will these veins be.

While experts are able to judge from the general build of a cow much as to her capacity as a milker, the various rules, or "points," which have been laid down for judging the merits of milch cows are of themselves uncertain. While the form of the udder is important, as also the size of the milk vein, a large, well-formed udder is not always a sign of productiveness.

The best cow in the province of Brandenburg, Germany, as shown in milking trials lasting for a year, was small and unsightly in appearance, and gave no external indication of so great productiveness. While the characteristics of the dairy cow, as regards conformation, temperament, etc., are helpful, intelligent breeders and feeders are exacting from their cows at least a certain yield of milk per year of quality that will assure them a profit in their keeping. The use of the scales and the Babcock milk-fat testing apparatus is of far greater value for determining the capacity of a cow than all the milk "signs" imaginable.

THE NUMBER AND SIZE OF FAT GLOBULES.

The fat is secreted in globular form, and the size of the fat globules in the milk is of great practical importance, since, as a rule, the larger the globules the cleaner will milk skim and cream churn. Studies on the number and size of the globules show that, as a general rule, there is a steady increase in number of the small globules and a decrease in the large globules as the period of lactation advances. From tests made in fractional milking it is learned that there is an increase in the number and size of the fat globules from the beginning to the end of milking.

There is an almost incomprehensible rapidity in the secretion of the globules. Assuming the milk secretion to proceed uniformly throughout the day in the case of 23 cows, each giving a little less than 20 pounds of milk, there was an average secretion of 138,210,000 globules per cow per second. A study of the size of the globules at the Pennsylvania Station showed the relative size of the globules to vary more uniformly with the total yield of milk than with any other factor. In general, a decreased milk production is accompanied by a decrease in the average size of the globules, and an increase in milk production from any cause is accompanied by an increase in the average size of the globules.[a] The influence of the quality and the quantity of food upon the size of the globules appears to be indirect, the real cause being the variation in milk production. If this is true—and the hypothesis is well supported by observations—the method of feeding

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[a] This statement needs further investigation and verification before being accepted as a principle or law.—H. E. A.

so as to produce the largest globules is the same as that required to produce the largest possible yield of milk consistent with keeping the cow in a normal condition.

IS THE FAT OF MILK A SECRETION?

Until recently the formation of fat has been commonly regarded as a result of a degeneration or breaking down of the epithelium cells of the gland. It has recently been shown that from the construction of the cells this position is untenable and that the formation of fat is not due to fatty degeneration, but rather to an infiltration of fat which the cells extract from the circulating supply of blood and lymph. The cell secretes, or separates, the fat itself by extracting it out of the fluids furnishing it and no breaking down of the cells takes place. This is not a mere transudation of the fat, as it may be, and usually is, very materially changed in character by the alveoli.

THE REGULARITY OF MILK SECRETION.

With the idea that the fat of milk was the result of breaking down the cells themselves, the thought that milk formation went on more largely at the time of milking than at other times was common. In experiments with Holsteins, Jerseys, Guernseys, and other dairy breeds, when the cows were milked at intervals of twelve hours each, it was found that the weight of milk secreted from 5 p. m. to 5 a. m. was the same as that secreted from 5 a. m. to 5 p. m. The average amount of milk in these trials and its composition are shown in the following table:

	Morning's milk.	Night's milk.
Yield .... pounds..	700	696
Water .... per cent..	86.25	86.39
Solids .... do....	13.75	13.61
Fat .... do....	4.26	4.22

This and similar studies upon the uniformity of milk secretion seem to warrant the belief that the milk is formed continuously and uniformly. The flow of milk at the time of milking is usually much greater than the capacity of the milk cistern, but this is readily accounted for, as the irritation of the nerves causes the contraction of the wall of the glands and milk ducts.

THE SOURCE OF THE FAT OF MILK.

As long as the theory that fat of milk was formed from the fatty degeneration of the milk gland and that it was not a secretion pre-

vailed, it was thought the fat of milk could not be directly derived from the fat of the food. Many experiments seemed to conform to this view, and it was consequently generally held that the fat of milk was derived from body fat. At the same time it was held by many that the supply of fat in food was always sufficient to more than account for the amount of fat in the milk secreted. The predecessor of the present director of the New York station compared, in the case of a large number of cows, the amount of fat in the milk with that in the food, and concluded therefrom: "It would seem that until strong proof shall be submitted that the fat of milk is derived from other constituents of the food its source at present must be held as the fat present in the food of the animal."

In experiments with a dog fed in different periods with nitrogenous and carbonaceous rations to which fat treated with iodin was added, it was found that a very considerable amount of the iodin fat was transmitted to the milk. In one case 23 per cent of the fat of the milk was iodin fat, while in a period immediately following, in which no iodin fat was fed, 6 per cent of the milk fat was iodin fat, which must have been derived from the body supply. These experiments indicated that body fat may be drawn upon for the production of milk fat, but that under like conditions the fat is more likely to be derived from the food fat.

By investigation it has been clearly shown that both protein and carbohydrates of food might be the source of body fat. The experiment which seems to indicate clearly that the carbohydrates may also be the source of milk fat was made by the present director of the New York station, and it is so important in its bearing on this question that a quite full abstract of the experiment is here given.

A cow fed during 95 days on a ration from which the fats had been nearly all extracted continued to secrete milk similar to that produced when fed on the same kinds of grain and hay in their normal condition. The yield of milk fat during the 95 days was 62.9 pounds. The food fat eaten during this time was 11.6 pounds, 5.7 only of which was digested; consequently at least 52.7 pounds of the milk fat must have had some source other than the food fat.

The milk fat could not have come from previously stored body fat. This assertion is supported by three considerations: (1) The cow's body could have contained scarcely more than 60 pounds of fat at the beginning of the experiment; (2) she gained 47 pounds in body weight during this period of time with no increase of body nitrogen, and was judged to be a much fatter cow at the end; (3) the formation of this quantity of milk fat from the body fat would have caused a marked condition of emaciation, which, because of an increase in the body weight, would have required the improbable increase in the body of 104 pounds of water and intestinal contents.

During 59 consecutive days, 38.8 pounds of milk fat was secreted and the urine nitrogen was equivalent to 33.3 pounds of protein. According to any accepted method of interpretation, not over 17 pounds of fat could have been produced from this amount of assimilated protein.

As to the source of milk fat, the conclusion is reached that in these experiments the milk fat was produced, in part at least, from carbohydrates, as previous experiments have demonstrated to be the case with body fat.

The quantity of milk solids secreted bore a definite relation neither to the digestible protein eaten nor to the extent of the protein metabolism. The extent of protein assimilation seems to be influenced mainly by the protein supply rather than by the quantity of milk solids secreted.

Neither a deficiency in the protein of the ration nor a depression of the digestible nutrients to about 5.5 pounds per day caused the cow to produce poorer milk. The only apparent effect was in changing the quantity of product. The changes in the proportion of milk solids were due almost wholly to changes in the percentage of milk fat.

THE RELATION OF THE NERVOUS SYSTEM TO MILK PRODUCTION.

Can the brain or nervous system of a cow affect her yield of fat? and, if so, in what ways and to what extent? are the interesting questions that have claimed the attention of many investigators. That cows have more or less power to "hold up" their milk is well known, but to what extent they may at will affect the actual secretion is not so clear. A comparison between the amount of milk drawn from a cow by a man and a calf was quite largely in favor of the calf. When cows are milked one teat at a time, both the yield and quality, at least for short periods, are decidedly affected. The yield of fat in such trials fell off from one-fourth to one-third of the yield when milked in the usual way (both teats from the same gland at the same time). Tests made upon these subjects indicate that change of milker, manner of milking, and change of environment all exert a more or less decided influence, temporarily at least, on the quantity and quality of the milk produced, the fat being as a general rule more sensitive to such changes than the other ingredients or the total yield of milk. In tests in which cows were milked in from three to four minutes and double that time, the yield of milk seemed to be very little affected, but in every case richer milk was produced when the cows were milked fast than when they were milked slowly. Many studies, by different investigators, on the effect of the frequency of milking and the studies of fractional milkings, seem to justify the following statements:

The secretion of any single ingredient, such as fat, is not affected by the act of milking.

No considerable formation of milk takes place during milking.[a]

Too frequent milking and allowing the milk to remain in the glands too long both tend to diminish the secretive activity of the glands.

The process of milking in itself is without effect on milk production. Frequent milking, within certain limits, may result in an increased production of milk not through the act of milking itself, but through the emptying of the glands.

EFFECTS OF TEMPERATURE AND WEATHER ON MILK SECRETION.

The effect of warm quarters upon milk production is uncertain. In a warm stable there is rather more milk and butter fat, on the average, than in a cold one, but in the climate of New England the increased production will not nearly pay the cost of artificial heating. The most certain effect brought out by these experiments is the lowering of the percentage of fat in the milk in the warm stable. With moderate artificial heat better ventilation can be secured without making the stable too cold for the comfort of its occupants than is possible without artificial heat.

In experiments upon the effect of warming the water used for cows it was found that there was an increase of 5 to 8 per cent in yield of milk and butter fat with water at 70° F. over that at 32° F. On the average more warm water was drank.

From studies upon the effect of weather upon milk production with many animals over long periods of time the following summary fairly represents the case:

There seems to be a general tendency of the quality of the milk to become richer in fat content when the temperature is falling and less rich during a rising temperature.

Concerning the changes in the milk occurring simultaneously with storms, if these changes are considered to be due to the effect of rain storms, they seem to indicate that cows in flush of milk on pasture feed give as much or more milk and of just as good quality in bad weather as in fair weather, and that when the storm is over they give a less quantity of richer milk. The cows do not appear to make any change in quantity or quality of milk on the approach of a storm, and no connection is traceable between the storms and the pounds of butter fat produced.

EFFECT OF EXERCISE AND FATIGUE ON MILK PRODUCTION.

It is found that with moderate work (not exceeding two hours a day) the yield of milk is decreased, the decrease being due to a de-

[a] This statement is still disputed by eminent teachers.—H. E. A.

crease in the water content of the milk, as the milk was more concentrated when the cows were worked. The principal effect is on the percentage and total amount of fat, both of which are increased. There is a decrease in all of the constituents of the solids except the fat, and especially in the case of milk sugar. Seven German experiments are reported in which a number of cows were driven a considerable distance, in some cases up a mountain, and the milk analyzed for a number of days before and after the trip. These experiments were made on different cows, in different parts of the country (Germany), and under varying conditions. They all showed that heavy exercise influenced both the quantity and quality of milk. The quantity of milk diminished and also the absolute amount of milk constituents. This decrease was more or less noticeable in the first milking after the trip, according to the severity of the exercise, and was much more noticeable in the second milking. The water content decreased in the first milking and more in the second milking, then gradually returned to the normal. The casein content increased in the first milking, remained about the same in the second milking, and then gradually sunk to the normal. The fat content was much increased in the first milking, according to the severity of the trip; was still larger in the second milking, and then gradually sunk to the normal. The sugar content decreased in the first milking and usually rose again to the normal in the second and following milkings. The ash content was noticeably higher in the first milking after the trip, and then sunk to the normal.

In two cases the effects of fatigue are reported where 10 cows were driven 10 miles and shipped 50 miles by railroad. While considerable individual variation was observed on the average, the quantity of milk was lowered as an immediate result, but normal flow was nearly restored by the end of the second day. The fat percentage dropped during the first day and was decidedly increased the second day, remaining a little high during the next few days, as compared with the flow of three weeks later. Solids not fat averaged about the same, except for the second milking. "It seems safe to conclude, as a result of the two tests, that fatigue tends to lessen the milk flow temporarily, to affect variously its quality for the first one or two milkings, and to raise the quality for a while after the second milking."

The above-cited results all agree in pointing out that causes and circumstances affecting the nervous system have marked effects, at least temporarily, on milk secretion. Usually circumstances which affect the animal unpleasantly decrease production. In these cases the fat is the constituent most considerably affected. Most of the experiments upon this class of subjects are of short duration, and

there seems to be a tendency under longer continuation of the conditions for the cows to adapt themselves to the change and gradually return to their usual secretion of milk.

COMPOSITION OF AND VARIATIONS IN QUANTITY AND QUALITY OF MILK.

As is well known, milk consists of water, casein, albumen, fat, milk sugar, and mineral matters. The exact amounts of these different constituents in case of different herds and periods of lactation vary within wide limits. As has been stated several times in this paper, the fat is the most variable as well as the most valuable of these constituents. So far as the quantity and quality (as measured by the butter fat) is concerned, the following statements seem to be justified by observations which have been made with a large number of cows of many herds for numerous periods of lactation.[a]

All cows shrink in quantity of milk as they get farther from calving. If they are farrow, this shrinkage in quantity is accompanied by almost no change in quality, even until they go dry, provided they are still farrow. If they are in calf, the milk increases in quality as it decreases in quantity; this increase is slight, only one-twentieth during the first six months after calving, but becomes quite pronounced just before the cow goes dry.

The milk of a cow for the first few days or weeks after calving is very variable in quality. On the average it is thinned just after calving, becomes slightly richer during the next two weeks, and then holds almost uniform in quality for the next four or five months.

Cows vary in the quality of their milk from one milking to the next and from day to day, the quality rising and falling without apparent cause. Such changes are usually within 1 per cent of fat, but it is probably possible that cases may occur of a doubling in the richness of the milk during different times in the same period of lactation.

The following illustrates the variation in percentage of fat which may occur in the milk of cows from day to day: The morning's and night's milk of a Jersey cow was analyzed on 8 consecutive days, the food, environment, and time of milking being exactly the same each day. The highest percentage of fat found was 5.32 and the lowest 4.45, a difference of 0.87 per cent. The variations which may occur from day to day in the composition of the mixed milk of a herd are illustrated by analyses of the mixed milk of a herd of 13 cows for a period of 32 days. The percentage of fat ranged from 3.63 to 4.59, an average of 4.19, and the amount of fat from 6.48 to 11.78 pounds per day.

Just after calving the milk is poorer in fat and in solids not fat

[a] A quite full discussion of this subject can be found in the report of the Vermont station for 1895, pp. 157–186.

than just before the cow goes dry. Most cows give about the same quality of milk year after year, beginning with this quality at the first calving. There is no general tendency for the milk to become either richer or poorer as the cow grows older.

From one calving to the next cows may be expected to vary the general quality of their milk not much more than a sixth of 1 per cent of fat, and scarcely ever will show an average variation of more than a quarter of 1 per cent.

EFFECT OF FOOD ON QUANTITY OF MILK.

There is a unanimity of opinion by practical men and scientific men alike that the food has a great determining effect upon the quantity of milk secreted. Feeding an insufficient ration under otherwise like conditions always decreases the amount of milk secreted. Abundant experiments indicate the importance of maintaining a proper ratio between the flesh-forming (protein) constituents of the food and the energy-producing constituents (the fats and the carbohydrates). The standard prepared by Wolff calls for each 1,000 pounds of live weight 2.5 pounds digestible protein and sufficient digestible carbohydrates and fats, so that the ration shall have a nutritive ratio[a] of 1:5.4. The standard suggested by the Wisconsin Experiment Station calls for 2.15 pounds digestible protein and sufficient fats and carbohydrates to make a nutritive ratio of 1:6.9, and the Storrs Station suggests a ration containing the same amount of digestible protein (2.5 pounds) as the Wolff ration and slightly more digestible fats and carbohydrates, so that the nutritive ratio is 1:5.6. Just what the size of the ration should be and what its nutritive ratio in order to get the best results is a matter of uncertainty, but that the size of the ration and its nutritive ratio are the determining factors on yield of milk is generally accepted. It seems to be well established also that dry fodders do not give as large a milk flow as succulent foods. At the Halle (Germany) Station it has been found that the milk flow increases regularly with the increase of watery foods until the water is carried above 100 pounds per 1,000 pounds live weight a day. To avoid misunderstanding on this point, it should, perhaps, be added that the results of experiments against feeding meals wet with water ("slops") seem to show decrease in the milk yield without affecting the quality of milk. In the case of cows changed from barn to pasture, it has been repeatedly found that there is a marked increase in milk flow, notwithstanding that most of the herds had grain while in

[a] The nutritive ratio is the ratio of the protein to the fuel constituents of the food, and is found by dividing the sum of the weight of the digestible carbohydrates and two and one-fourth times the weight of the digestible fat by the weight of the digestible protein contained in the ration.

the barn and none while on pasture. The increase which comes when the pastures are dry in the late summer from the feeding of corn fodder is marked and well known. Time and space will not permit a summary of the work along the lines of the effect of food upon the quantity of milk secreted, but the following results are typical of the reports of most exact feeding tests on the subject:

EFFECT OF RATIONS OF VARYING NUTRITIVE RATIOS ON THE SECRETION OF MILK.

The animals were fed in four periods. First the nutritive ratio of 1:8.2, second the nutritive ratio of 1:5.4, third the nutritive ratio of 1:4.3, and fourth the nutritive ratio of 1:8.2, the same as the first. All three rations contained practically the same amount of dry matter and very nearly equal amounts of digestible nonnitrogenous matter. Cows were milked three times daily, and daily analyses were made of the mixed milk of each cow. There was little variation in weight from day to day. There were no changes in the percentages of fat which could be attributed to changes in the food. In the amount of milk and the total amount of fat there were marked changes.

In the case of each cow the absolute yield of milk and fat increased with the increased protein consumption, this being greatest with the change from the first to the second ration. When the cows were changed back to the wider ration in the fourth period, they all shrunk in the yield of milk and fat.

There was a gain in weight on the rations of the second and third periods, and a loss on that of the fourth period. The results show that it is possible by rich feeding to maintain a yield of milk and fat well up to the end of the period of lactation, and that, on the whole, liberal rations, and especially rations richer in protein than Wolff's standards, were the most advantageous.

LEHMANN'S STANDARD RATION FOR MILCH COWS.

The experiments in this country and abroad seem to indicate that for the production of milk there is need of a liberal proportion of protein in the food. Just why so much protein is necessary physiology is not yet able to clearly explain. It has been suggested that the influence upon milk secretion of an abundant supply of digestible protein in the ration is due to the influence of protein upon metabolic activity rather than because so much is needed to form milk solids. Whatever the explanation, the fact seems fairly well established that a liberal supply of protein is favorable to increase in the amount of milk secreted.

The feeding standard prepared by Wolff thirty years ago was modi-

fied by him from time to time in accordance with the teachings of experience and experiment. Recently Dr. Lehmann has made changes in this standard for milch cows so as to provide rations fitted to the actual milk production. In these standards he has made the ration narrower as the amount of milk secreted is larger. The standard rations, as prepared by Dr. Lehmann for cows per 1,000 pounds live weight with different milk yields, are as follows:

Milk per cow per day.	Protein.	Fat.	Carbohydrates.	Nutritive ratio.
Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	
11	1.6	0.3	10	1:6.7
16	2.0	.4	11	1:6.0
22	2.5	.5	13	1:5.7
27	3.3	.8	13	1:4.5

EFFECT OF FOOD ON QUALITY OF MILK.

The question of the effect of food upon the composition of milk has called forth a variety of opinions and much experimental work, and is at present regarded by many as unsettled. In the opinion of most investigators, after a certain point is passed food is only of secondary importance, and the quality of the milk depends upon the natural capacity of the animal and the glands for secreting milk. By some investigators and by many practical feeders this point is not considered as settled.

CAN THE PERCENTAGE OF FAT IN MILK BE LOWERED BY SCANTY FEEDING?

In the case of short periods (ten days to three weeks) the results of the experiments seem to be entirely consistent with the conclusion that scant feeding or the feeding of unbalanced rations exerts an entirely insignificant influence on the fat content of milk. The results of all these experiments which have come to my notice are summed up in the following conclusions of one such test:

The animals were fed for two weeks on rations which were insufficient. The cows lost in weight, and in some cases there was a slight shrinkage in yield of milk, but the composition remained practically unchanged, indicating that it is the flesh of the animals that first declines when the aliment is insufficient.

In the case of long-continued, scantily, and poorly balanced feeding, it seems to be clearly established that the fat content of the milk may be materially reduced below the normal. This is illustrated by observation upon cows in Norrland. During the period from January to May, Norrland cows are in general fed only a meager allow-

ance of marsh hay and are therefore in a very poor condition when turned out to pasture in June. The results of about 2,000 analyses for these periods of feeding show that on rich pasturage their milk carried from 2.65 to 5.8 per cent, with an average of 4 per cent of butter fat, and that on scant stable feeding the milk carried from 1.10 to 4.6 per cent, with an average of 3.25 per cent of butter fat. In discussing these results the author concludes that the fat content of milk can not be increased at will by increasing a normal ration, but, on the other hand, that it can be greatly decreased by scant and poor rations. If a change is made from a deficient to a normal ration, the fat content of the milk will again be raised to the limit determined by the inherent qualities of the individual cow. This point is more or less generally accepted and is of practical importance in the case of ordinary feeding only, as it indicates that cows may be below their normal for some reasons, and that a proper ration may apparently increase the percentage of fat, when in reality it is only bringing the animals up to their normal quality of milk.

CAN THE PERCENTAGE OF FAT BE RAISED BY LIBERAL FEEDING?

Up to the time of the publication of a paper by Soxhlet in 1896 there was little diversity of opinion among American investigators on this subject. It was generally accepted that the addition of nutrients to an already normal ration would not increase the percentage of solids in the milk or the percentage of one or more of the constituents of the solids. Hundreds of feeding experiments with cows on different rations have been made in which the milk has been analyzed and exact records of the percentages of fat have been kept. These tests have been made with all kinds of feeds and with a very general agreement that changes of feed when cows were previously well fed were without effect on the composition of the milk. The general opinion among investigators, at home and abroad, is illustrated by the following abstracts from the results of feeding experiments in many countries with many animals:

A Danish investigator, speaking of extensive feeding experiments in Denmark, says in substance: The experiments prove that the feed under practical conditions, as found in this country, exerts an entirely insignificant influence on the fat content of the milk.

Another investigator says: The complete chemical analyses of the samples of milk from the different lots failed to disclose any decided difference in the composition of the milk attributable to the different concentrated foods fed, and the author therefore concludes that in the comparative feeding trials with milch cows now continued for seven consecutive years at this station, in which 1,639 cows have been included (separated into 161 lots on 10 estates in different parts of

our country), it has been found over and over again that the changes made in the food of the lots have had practically no influence on the chemical composition of the milk. In these experiments grain has been fed against roots, against oil cake, and against wheat bran or shorts; grain and oil cake have been fed against roots, or roots have been fed as an additional food.

An investigator in Scotland, speaking of the results of his experiments, says: These experiments plainly indicate that while many foods appear to have a tendency to enrich or impoverish the milk, still neither effect is permanent, the inclination after a time being for the milk to return to its more normal composition.

The consensus of American investigators on the effect of different rations is illustrated in the discussion of the results of a feeding experiment which may be concisely stated as follows:

About 5 per cent more milk was produced on 2 pounds and 10 per cent more on 2.5 pounds of protein daily than when the animals received 1.5 pounds each. The quality of the milk was scarcely changed.

Such was the situation in 1896, and the subject would have been considered closed, with the evidence all in and verdict rendered, had it not been that in that year a distinguished German investigator published a brief account, without giving the data, of experiments in which the percentage of butter fat was materially increased in milk by feeding tallow in the form of emulsion. In this paper Professor Soxhlet pointed out that in some of the experiments which have been regarded as conclusive on certain points and which have had much to do with shaping the general opinion of the effect of food on milk, rations were fed which were less digestible than was assumed, *i. e.*, that the particular substances tested, like fat, were added to the basal ration in such form that they were not digested by the animal. Hence no effect could be reasonably expected. His investigations led him to believe there is no direct transmission of fat from the food to the milk, as some have held, but that normal milk fat is a product of the activity of the lacteal glands, and that its source is the body fat of the cow. The fat of the food affects the secretion of milk fat by replacing a part of the body fat, and thus causes a transmission of the body fat to the milk. He is confident that the fat of the food can effect a one-sided increase in the fat content of the milk; but he states that fat is the only food constituent capable of doing this.

The first brief account of Soxhlet's work is all that has been given, and whether the experiment was confined to one cow and whether the reported increase in yield of fat was continued more than for a few days is not known. As the result of the publication of this experiment a renewed interest was taken in the subject and numerous

experiments have been made. While the later findings are not in accord with Soxhlet's results, they are of sufficient interest to warrant a brief review, particularly as they have led to a series of experiments on the effect of fat in food upon butter, which is discussed further on.

Tallow feeding at the New York Cornell Station resulted as follows: Five cows of different ages kept at pasture were fed a ration of equal parts of wheat bran and cotton-seed meal, with the addition of cornstalks, silage, or hay, when the pasture began to fail. For ten weeks they were given tallow in addition, beginning at the rate of 4 ounces per animal daily, and gradually increasing the amount 4 ounces at a time until each cow was eating 2 pounds daily. Similar experiments were carried out with 5 two-year-old heifers which had recently calved, and a winter trial was also made with 5 two-year-old heifers which had recently calved.

No difficulty was found in getting the animals to eat the tallow. The health of all the animals remained good, and no appreciable change in live weight took place. There was no marked change in the percentage of fat and yield of milk in the period when the cows were on a full feed of tallow. While there were slight variations in the percentage of fat, they rarely reached 0.5 per cent, and, what is of more significance, they were not uniform. Some of the cows gave richer milk and some poorer on a full feed of tallow than they did before or after.

In experiments at the New Hampshire Station the first effect of feeding oils was to increase the fat in the milk. The sharp increase in fat was followed by a decrease until the milk again reached its normal composition. The results of this work are summarized as follows:

The first effect of an increase of fat in a cow's ration is to increase the percentage of fat in her milk. With the continuation of such a ration the tendency is for the milk to return to its normal condition. The increase in fat is not due to the oils, but to the unnatural character of the ration. The results in this experiment tend to confirm the conclusions that the composition of a cow's milk is determined by the individuality of the cow, and that, although an unusual food may disturb for a time the composition of the milk, its effect is not continuous.

The results of German experiments suggested by Soxhlet's results show that the percentage of fat in the cow's milk, as a rule, increased during the first four to six days of oil feeding, in single cases, nearly 1 per cent; after 10 to 25 days, however, the fat content again became normal in spite of the fact that the oil-emulsion feeding was continued. The yield of milk and of fat changed with the oil feeding in the same manner as the percentage of fat in the milk. Another German investigator finds as the result of experiment that the fat

content of the milk was increased at first by feeding large quantities of oil in the form of an emulsion, but later on no increase took place; the milk, on the contrary, dropped to its previous normal fat content, depending on the individuality of the cow.

These experiments, on the whole, indicate that the effect of even very abnormal food materials is not to alter permanently the composition of milk, and one is forced to the conclusion that Soxhlet published prematurely the results of too short experiments. The final conclusions thus far reached indicate that the further addition of nutrients to a normal ration has little or no permanent effect upon the percentage of fat in the milk. The results of these experiments and others of similar kind are making clear the necessity of using long (four weeks or more) feeding periods and the unreliability of conclusions based upon tests of only a few days' duration.

EFFECT OF FOOD ON BUTTER AND THE COMPOSITION OF BUTTER FAT.

The experiment reported upon by Soxhlet which led to the feeding of oils and fats stimulated a study upon the relation of the character of the fat of the food and that of the milk, and tends to throw some light upon the source of the fat of milk.

Investigations by the stations made nearly ten years ago agreed in giving conclusions, of which the following are typical:

The tendency of butter to melt during hot weather may be influenced by the kind of food and also the degree of hardness may be affected.

A mixture of cotton-seed meal or linseed meal with corn meal and wheat bran, especially the cotton-seed meal mixture, produced butter less easily melted and of a more solid appearance than did the peas and barley.

Gluten products containing large percentages of oil produce soft butter. Gluten meal tends to make soft butter, while cotton-seed meal tends to make a hard butter. The hardness of butter seems to depend more upon the character of the food than upon its nutritive ratio.

The recent feeding of oils and fats as large parts of rations has given results upon the composition of the fat of milk and butter, of which the following are fair illustrations:

Cows fed on cotton-seed oil produce milk the butter fat of which gives cotton-seed oil reactions. The reactions appear when the cows receive only a small quantity of oil. They increase somewhat with continuous feeding, but apparently can not be carried beyond a certain point. The reacting substance passes into the milk within less than twenty-four hours after the feeding begins and continues to do so for several days after it has been dropped.

The same oil had a marked influence on the appearance and taste of the milk and increased the index of refraction, diminished the volatile fatty acids, and increased the iodin number of the butter. The butter produced on cocoanut oil was normal in appearance, but had an unmistakable taste of cocoanut oil. The index of refraction of the butter was materially diminished, the volatile fatty acids were slightly increased, and the iodin number was noticeably diminished. On almond oil the butter showed a positive increase in the index of refraction and the iodin number increased. The authors conclude that the feeding of oils not only greatly changed the butter, but that the changes followed in general the characteristics of the oils themselves.

The examinations of the butter fat showed that the volatile fatty acids decreased greatly during the linseed-oil feeding. This effect of the oil feeding was much more persistent than on either the yield or fat content of the milk, and on discontinuance of the oil feeding the return to a normal volatile acid content came but slowly. The iodin number rose and fell rapidly with the feeding of oil and discontinuance of it. As only small quantities of linoleic acid were found in the fat, the increased iodin number must have been due to an increase in the olein content of the fat on oil feeding. The index of refraction changed in the same manner as the iodin number, the curves for the two sets of determinations following each other closer throughout the experiments. The increase due to the oil feeding was very marked and rapid, with the maximum appearing about the fifth day of the oil feeding. The melting point of the fat increased in the same manner as the iodin number—namely, from 35.4° to 39° C.

The above results seem to warrant the general conclusions that when a large quantity of fat is supplied to the animal organism in the food it will, after having been transferred to the blood, be secreted as milk fat, but the secretion can not be looked upon as a direct transmission of the fat from the blood to the milk glands. The fat added will be worked over in passing through the alveoli cells of the milk gland in such a manner that a large amount of olein and a small amount of a fat having a high melting point are formed. If there are large quantities of drying oils in the fat consumed, these will be changed to nondrying oils before being secreted in the milk.

SOME OF THE CONCLUSIONS REACHED.

Although the physiological side of milk production is incompletely understood, and there is need of much investigation before definite statements can positively be made, the results of a present knowledge seem to warrant the following general summary:

The secretion of milk is closely related to the nervous organism of

the cow, and anything which affects the nervous system may temporarily affect both the quantity and quality of the milk. Under normal conditions, milk secretion proceeds uniformly during the twenty-four hours. Under usual conditions, the fat of the milk is partly derived from body fat, but chiefly from the fat of the food. The fat is not directly transmitted from the blood, but is modified and worked over by the alveoli of the udder. The quantity of milk is largely determined by the quantity and quality of the food. Under usual conditions the quality of the milk is but little affected by the food. If for any reason the quality of the milk is temporarily changed, there is always a tendency to return to the normal.

When a cow in good condition is in full milk she will give her normal quality of milk at least for a limited time, even though the quality or quantity of her food is deficient.

When in good condition a heavy milking cow will take flesh or fat off her body in order to give her normal quality of milk.

If the food ingredients are present in sufficient quantity, in a state palatable to the animal and easily assimilated, it does not seem to make much difference from what source they come.[a]

The percentage of butter fat in milk is very little influenced by foods containing a large percentage of oil, such as linseed or cotton cake, nor yet by albuminous foods, such as bean or pea meal, decorticated cotton cake, etc.

The composition of the butter fat is modified within narrow limits by the fat of the food.

An increase in quantity and quality of milk over the present normal standard or average product is to be looked for more from breeding than from feeding.

There is a tendency for the milk capacity of the cow to be transmitted to her descendants with usually only small changes in quality and quantity. By proper feeding, a heifer can be developed to give the normal quality of milk of the dam. How far the quantity may be thus increased is unknown. The hope of improvement of dairy cattle is in wise breeding and in careful selection and judicious feeding of the young stock.

DISCUSSION.

NOTE.—The foregoing paper was read by Professor Woods at an annual meeting of the Connecticut State Board of Agriculture, and was followed by a discussion, from the full report of which the following extracts have been made:

There is a general tendency for the milk to have the same quality throughout the entire history of the animal, from a heifer to old age; that is, the heifer that gives milk of a certain richness will not be apt to vary much from this quality as

[a] In other words, one kind of food is as good as another, provided there is enough of it and it is well proportioned or "balanced," and that it is in character satisfactory to the animal.

she increases in age. There may be a very slight increase in the percentage of fat as age advances, but average figures show the whole variation to be only about one-sixth of 1 per cent.

In succeeding generations improvement in both quantity and quality of milk produced may be expected, resulting not from any one cause but from a combination of judicious breeding, feeding, and treatment.

Secretary T. S. Gold said: "There is one way by which I can reconcile these different statements. The professor says when you feed a normal ration, by adding to it you can improve the quantity and quality of the milk only for a time, but you can not increase it beyond the normal yield permanently. Now, as dairymen, do we not generally allow our cows, in that particular period that has been referred to, just between grass and hay, to live on something below the normal ration—that is, frozen grass and other materials of that kind? And, when we come to give them meal or to put them in the barn and give them good food, we know the product we get is better—better cream and better milk. Half-frozen grass is not a normal ration. A cow will not eat it as well, and, of course, can not be expected to do so well. She never will make first-class milk on such food. It seems to me that Doctor Atwater offered a very suggestive remark in this connection this morning. When our cows are fed on such imperfect rations, do they not require all the nutriment there is in the food for their keep, instead of producing rich milk? The cow grows poor and gives poor milk, consuming the fat in the system. I think we are not so far apart as we might be on this question. I think if we give our cows good normal rations, and they are healthy cows, it will be found difficult to improve the butter or the milk very much."

Ex-Governor W. D. Hoard said: "In Wisconsin we have gone through experiments on this very subject that have cost us over $2,000, to see if we could feed butter fat into the milk or increase the percentage of butter fat. It can not be done. Now, understand that. We will suppose that a cow is giving 4 per cent butter fat in her milk. Can we feed her so that she will give 5 per cent? Many men think so. I have tried it in so many ways that I have given up trying, because it can not be done. I can increase the amount per day, temporarily, of butter fat. I can increase the amount per day, but I have never been able to make any perceptible change in the relation of the solids to each other. For instance, there is 3.5 per cent casein, 4.7 per cent sugar, and 4 per cent of butter fat; and there it stays right along. I have never been able, in all the time that I have been at work at it, to effect any change in the relation of the solid constituents. If it were so, good friends, don't you see it would be very easy to take a Holstein and make a Jersey of it; or very easy to take a Jersey and make a Holstein of it, if you could change the per cent? The percentage is practically fixed. What is the reason, then, that some cows give a richer milk than others? Because they are bred so, and not because they are fed so. At our creamery there have been over 27,000 tests made on milk. We made 12,000 tests at one time in all conceivable ways—chemical analyses, tests of the Babcock apparatus, and all sorts of tests, and I want to tell you what I know. There is a temporary variation sometimes. It passes up and down like the mercury. But, notwithstanding that, I know it is not lasting, because there are certain other causes which change it the other way and change it back to about the normal standard. All sorts of conditions affect the cow's cream—feeding conditions, stabling conditions, etc.—all these things do produce a temporary variation. Some of these things may make a difference in the cows, and hence a change of feed might sometimes stimulate the secretive organs, and you do improve the flavor, and your lactometer will change up and down in the milk, but it is simply temporary. The average percentage remains about the same."

Dr. E. H. Jenkins said: "No one can rationally discuss the result of feeding or the effect of feeding upon butter fat in the milk unless he has weighed the milk from every milking, and unless he has determined the fat either by the Babcock test or by some other laboratory method. An examination of milk which has been shipped from Litchfield down to New York is not likely to show exactly what the cows give in that locality. I have seen train hands drinking out of the cans, from the cover of the cans, and then filling up the cans with water in such a way as to make the quantity appear correct, and, by just so much water as they poured in, the milk was deficient. The lactometer, as the sole test used by the wholesale dealers in New York, shows absolutely nothing as to the contents of the milk. The less fat you have the higher specific gravity you get. This is a subject which can not be discussed in a rational way unless the quantity of milk at each milking is known, and the percentage of fat in that milk shown by the Babcock test, or by some other laboratory test. Now, I think that wipes out considerable of this so-called practical knowledge with regard to the effect of feeding on the amount of the fat in the milk. If you do not know how much milk a cow gives at every milking—if you do not know the percentage of butter fat in every milking that she gives—there is no use in discussing it at all, because it is impossible to make any rational conclusion."

Professor Woods concluded: "I am not here in the attitude of arguing the matter either one way or the other. The scientific man is simply looking for facts. I take the facts as I find them and report them to you as honestly as I know how; and, as a result of all the observations I have made, I find that it comes down to this: The quality of the milk is something which is inherent in the animal, and is affected by food only within very narrow limits, when affected at all. I am free to admit that there are various things that will temporarily affect the quality of the milk, but I can not imagine that there can be a very radical change in the quality in a change from one kind of food to another food. There may be a temporary change in the quality of the milk, but there is always a tendency of the animal to return to her normal standard, or regular inherent richness."

THE PHYSIOLOGY OF MILK SECRETION.

With notes on the effect of foods, drugs, exposure, exercise, and abnormal bodily condition.[a]

By A. W. Bitting, M. D.,
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THE PURPOSE OF MILK SECRETION.

In reproduction among the higher animals, the offspring at birth are not sufficiently matured to be able to subsist alone; neither are they surrounded by food that is already prepared for them. It is therefore necessary that nature should provide for a part or whole dependence upon the mother for subsistence during such time as is required for development to a state capable of independent existence. As a means to this end, we find a mammary gland in a very large group of animals, the secretion of which is known as milk, and is

[a] Extracts taken by permission from an article in The Creamery Patron's Handbook.

a perfect food. Milk contains all the nutriment required by a growing body, in proper proportions, in a palatable and easily digestible form. For these reasons persistent efforts have been made to domesticate animals and develop this function to the highest degree as a source of food for people. How successful these attempts have been is exemplified in the milking capacities of several animals now used for this purpose. Animals in a wild state furnish a quantity of milk only sufficient for the young, and only for such time as is necessary for their maintenance. Under domestication the cow in particular has been developed to produce a quantity sufficient to support several offspring and to keep up the secretion almost continuously.

THE MAMMARY GLAND.

The mammary gland being an accessory organ of generation, it is but natural that it should be rudimentary at birth and without function. It remains in this condition until the reproductive function becomes active, at which time it begins to develop quite rapidly and continues to do so until the end of the first period of gestation. Like other organs of the body, it grows with the general growth and also from usage. Its functional activity does not ordinarily begin until near the close of the period of gestation, reaches its maximum at from ten to fifteen days thereafter, and then gradually declines and practically ceases in from six to ten months. If the gland should be examined at birth a white fluid will be found in the ducts, but it is not true milk. True milk may occur, however, at a very early date and without the stimulus of pregnancy. A case, as follows, came under the notice of the writer: A farmer gave a young calf to his son to feed and care for. The little fellow began going through the motions of milking his pet and in the course of a few weeks surprised his father by producing a half pint of milk. While this is an exceptional quantity for a young calf, the observation has frequently been made that small quantities will be present in the udders of calves that suckle each other while being weaned. Gabby reports the case of a heifer that had never shown signs of œstrum suddenly developing a large udder and was milked constantly for three years.

The male is possessed of a rudimentary mammary gland, but the writer is not aware that it ever develops functional activity under any form of stimulus in the lower animals.[a]

THE MILK GLOBULES.

When milk is examined under the microscope it appears as a clear liquid, in which are suspended an immense number of spherical bodies

[a] Bulls of dairy breeds have been known to produce small quantities of milk from the rudimentary teats.—H. E. A.

that are of a light yellowish appearance and are highly refractive. These constitute the fatty part of the milk and are known as milk, or fat, globules. Their small size and the viscous nature of the milk serum tend to prevent the coalescence of the globules. The size of these globules varies in all milks from 2 μ up to 30 μ in diameter.[a] The size also varies with the milk drawn, whether it be first, middle, or last drawn, as may be seen by the following records:

Number of globules of each size per 1,000 globules.

Size in μ.	First milk.	Middle milk.	Last milk.	Whole milk.	Skimmed milk.
4	95	18	68	70	365
6	220	90	153	190	425
8	427	215	238	319	120
12	152	443	204	180	54
16	67	180	127	121	24
20	20	54	85	76	12
24	10	0	25	19	----------
28	9	0	0	----------	----------

As the period of lactation advances the globules increase in number and the average size diminishes, so that after several months the total number of globules per cubic centimeter may be two or three times as great as at first, but the size correspondingly smaller; the percentage of fat remains approximately the same.

P. Collier records[b] the results of a large number of determinations of the size of the globules in the milk of different breeds. The size of the globules diminishes as the period of lactation advances; that is, the relative number of large globules diminishes and the smaller globules increase. He found[c] that the relative number was 100 in the first quarter, 137 in the second quarter, 149 in the third quarter, and 187 in the fourth quarter of the period of lactation; that is, a given quantity of milk contained 89 per cent more fat globules in the last quarter than in the first.

O. Schnellenberger[c] found essentially the same thing, and estimated that a liter of milk contained 2,480,000,000 globules at the beginning and 4,449,000,000 globules at the end of the period of lactation.

F. W. Woll agrees with the previously cited writers, and further adds that age has no apparent effect, and that the morning milk contains more large globules than the evening milk.

The milk from certain breeds, as Jerseys and Guernseys, is char-

[a] 1 μ equals 1-25000 of an inch.

[b] New York Experiment Station Report, 1891.

[c] Experiment Station Record, Vol. V, p. 95.

acterized by large globules, while that of other breeds, as Ayrshires and Holsteins, usually contains small globules. There is, however, a wide individual difference in all breeds, Jerseys sometimes producing small globules and Holsteins large ones. In normal milk the globules are uniformly distributed throughout the whole mass, but to a greater or less extent collected in groups. For a long time it was thought that each cell was surrounded by its own membrane, the membrane of Acherson. This membrane was supposed to be derived from the cell of protoplasm. According to Babcock, no such membrane exists, and he is supported in this view by nearly all recent investigators. It is now considered that milk is a natural emulsion, and that what appears to be a membrane is not different from what is seen in other emulsions having the fat similarly divided.

QUANTITY AND QUALITY OF MILK SECRETED.

Wild animals secrete only a sufficient quantity of milk to meet the needs of their young until they become sufficiently developed to secure their own food. Under the influence of domestication the functional activity of the gland has been greatly developed both in the quantity produced and in the duration of the period of lactation. In all good dairy cows the period should extend over several months, and in some it is practically continuous. The average yield per cow is less than 4,000 pounds per annum; but in good dairies it is more nearly 6,000 pounds, and in individuals it will greatly exceed that amount. In one instance it was over 30,000 pounds. The flow of milk is greatest shortly after parturition and gradually decreases until the close of lactation.

As milk is dependent upon the metabolism of the mammary gland, this is in turn dependent upon the quantity of blood passing through it. For large milking capacity it is necessary that there should be large glandular development; but, more important still, a large circulation of blood in the part. The cow must receive an ample supply of food and have the capacity to eat, digest, assimilate, and turn into blood the elements necessary to form milk. Some time after parturition there is a tendency toward a shrinkage of the vessels of the udder, and this becomes more marked as the period of gestation advances. All the excess nutrition of the body is needed for the developing fetus, and hence a lessening of the functional activity of the gland. That pregnancy is an influence tending to diminish milk secretion is demonstrated by the fact that spayed cows will continue to produce milk a long time, even from two to five years, during which time the quantity and quality make a very gradual decrease. While pregnancy has its influence upon the period of lactation, there are other factors that are of even greater importance and can not be overlooked, the

most important of which is the regularity and thoroughness of the emptying of the gland. If the milking process be done at irregular intervals, or incompletely, the activity of the gland soon ceases. Shortage of feed or water or disease may result in immediate cessation of secretion. The ordinary period of lactation is from nine to ten months throughout the life of the animal. The first and second periods are somewhat shorter.

The quantity and quality of milk secreted each day is fairly constant. Variations do occur within certain limits and may be due to numerous causes. In general, the evening milk contains about 0.5 per cent more fat than morning milk, but the latter exceeds the former by about 25 per cent in quantity. An attempt has been made to explain this by attributing it to the fall in temperature during the night, requiring some of the fat to keep up the body heat, and to the lessened activity of the animal. Fleischmann and Veith experimented upon a German herd of 119 cows, and found that the fat in the evening milk not only varied within wider limits than in the morning milk, but also observed that from March until July, the period of greatest activity of the gland, the morning milk was richer in fats than the evening milk. The difference in the quantity of milk drawn morning and evening is due in part to the greater length of time allowed to elapse between the evening and morning milking. This may possibly also account for some of the differences in the percentage of fat. In general, the milk richest in fat is that drawn after the shortest period, and this has been shown to be true in cases where cows have been milked three or four times a day. After a third or fourth week of lactation the percentage of fat in the milk remains nearly constant until the seventh or eighth month or until the quantity of milk begins rapidly to diminish.

The daily variations in the milk are sometimes considerable. Such variations may be ascribed to changes in the weather, temperature, food, surroundings, indisposition, etc.

The monthly variations in the quantity and quality of the milk are less marked than the daily variations. Cows coming fresh in the spring rapidly better the quality of their milk, beginning about five months after calving, but cows calving in the fall maintain a fairly even quality throughout their entire period of lactation. The quality of milk is augmented when cattle are first turned out to pasture and during drought, but this must be ascribed to food conditions, and not to seasonal variations. The richest milk is produced after the seventh month.

The yearly changes in quantity are slight. The increase in the second and third producing years is marked, but after that it is rarely more than 3 per cent. The changes are so dependent upon feeding that no conclusions can be drawn upon this point.

FAT IN FORE MILK AND END MILK.

There is considerable difference in the percentage of fat in the milk taken at the different parts of the milking. Schmidt made complete analyses of first milk drawn and last milk drawn, and found that this difference was almost wholly due to the fat, there being eight times more fat in the end milk than in the fore milk. We have made many tests of the fat and found the percentage to be about five times as great in the end milk as in the fore milk. A possible explanation offered for this is that the fat at first lodges or adheres to the lacteal ducts, and that in reality a separation of cream begins in the udder, and this fat would, so far as circumstances permitted, seek to float on the denser fluid in the cisterns and teats. The udder of a cow killed immediately after milking showed on examination that the ducts contained a residue of rich milk, and it is probable that the whole of the fat is never drawn at each milking.

THE ELABORATION OF MILK IN THE ANIMAL ORGANISM.

There has been a large number of theories advanced as to the methods by which milk is elaborated, most of them based upon the assumption that it is a comparatively simple chemical and physical problem. All the earlier theories were based upon such assumption, the physiologists regarding the mammary gland as an organ to separate certain elements from the blood in definite proportions as milk. It was regarded that the process was largely one of transudation through a special membrane, on the same principle that exchange of gases by osmosis occurs rapidly in the tissues of the lungs. It was assumed that the fat of the food and the water and the salts taken into the alimentary canal were absorbed and taken into the blood and then eliminated by the mammary gland. The milk serum was regarded as escaped blood serum, and that the other particles were derived from the blood or epithelial cells. The gland was assumed to be a semipassive organ, receiving the milk already prepared, and only requiring elimination in the proper proportions.

It was upon the foregoing assumption that the great majority of experiments have been made for the purpose of augmenting the quantity or quality of the milk. If this assumption were correct, then the quantity or quality of milk produced would only be limited by the ability to digest and assimilate food.

Probably the most satisfactorily planned and executed experiment to settle this theory was made by Jordan and Jenter.[a] The object was to determine whether the fat in the milk was derived from the fat in the food. During the entire experiment of fifty-nine days analyses

[a] Bul. No. 132, New York State Experiment Station.

were taken of the feeds and milk, and the urine and feces collected, to determine where everything had gone. For two weeks the cow (a grade Jersey) was fed on 10 pounds of timothy hay, 6 pounds of corn meal, 5 pounds of ground oats, and 1 pound of wheat gluten. Then the same foods were fed with all or very nearly all the fat extracted. For a short time after the change there was a decided variation in the milk solids, but this was soon overcome, and the milk regained its normal composition and maintained it with only slight variations, which could not be assigned to any cause, throughout the entire period. The milk-fat yield for the seventy-five days was 62.9 pounds, and the fat contained in the food 11.6 pounds, of which only 5.7 pounds were digested. The extra fat could not have come from the previously stored body fat, because in the beginning of the experiment the cow was thin in flesh and gained 47 pounds of body weight, and was judged to be a fatter cow at the end than at the beginning. The milk fat could not have come from the protein, because during the fifty-nine consecutive days 38.8 pounds of milk fat was secreted and the urine nitrogen was equal to about 33 pounds of protein. According to any accepted method of interpretation, not over 17 pounds of fat could have been produced from this amount of neutralized protein. For the greater part of the milk fat they could draw no other conclusions than that it is formed, partially at least, from the carbohydrates. Several experimenters have proved that body fat may be formed from carbohydrates, and the foregoing experiment only strengthens the analogy between milk and body fat in this mode of formation. This experiment completely disproves the transudation theory, as the conditions under which it was conducted were wholly under control. It further offers an explanation for the results of many other experiments conducted along the same line, but not so completely carried out.

The transudation theory also meets a serious setback in the fact that the fats in the milk are unlike the fats in the food or body, and that casein and milk sugar are not found in the blood or the gland itself.

Another theory that has had many supporters is that milk is the result of the separating of part of its constituents, as the water serum and salt from the blood, and part due to a fatty degeneration of the cells lining the alveolar cavities, the fat globules being due to the degenerated cells and the casein due to the undegenerated portion of the cells. This theory is actively supported by many of the best physiologists. Smith, after examining all the phases of milk secretion, sums up the whole as follows: "The process of milk secretion may therefore be regarded as a process of metabolism of the epithelial cells, which undergo decomposition and discharge the resulting products into the excretory ducts." He regards "fat as a product of fatty degeneration of the protoplasmic cell contents, for it is not increased,

but actually diminished, by an increase of fat in the foods. On the other hand, an increase of proteids in the diet will cause an increase in milk fat. In microscopic examination of the epithelial cells of the mammary gland, oil globules may be actually seen to increase in size and number until often the protoplasmic content becomes almost entirely replaced by oil globules which entirely agree in their characteristics with the oil globules found in milk." In feeding animals on a highly albuminous diet they increase in weight and produce more fat in the milk, at the same time showing that they can not be filling the pail from adipose tissue. However, in herbivora not enough albuminoids are being taken up to account for this fact, so that some must be derived from the blood.

P. Collier made an investigation [a] to determine the number of fat globules found in milk in a given time. He made his observations on a large number of cows and found that on an average each secreted seven-tenths of a pound, or nearly 19.6 cubic inches, of milk per hour, and that there were 152 fat globules in each 0.0001 cubic inch of milk. He concluded that this was equivalent to secreting 136,000,000 fat globules per second. He duplicated his work on 23 other cows and found they secreted an average of 138,200,000 fat globules per second. Collier also recognized the fact that milk contains ingredients that must be the result of some special activity, as the casein and milk sugar are not present in the blood and the fat only in traces, thus precluding the possibility of being derived by transudation. A good cow may produce 2.5 kilograms (5 pounds) of albuminoids, fat, and sugar. The weight of the total solids of a gland producing that amount of milk solids is only about 1.16 kilograms (2.25 pounds), which would necessitate a complete renewal of tissue 2.09 times a day. He might have added that the epithelial cells constitute only a small part of the gland structure, and it would therefore require even more rapid renewal. This would require an almost incredible cell growth, so that we are forced to assume that, although the growth and disappearance of certain cells is of the greatest importance, the organic substances in milk are modified from substances in the blood and lymph into the forms we find them in milk by the functional activity of the cells. The estimates upon the rate of cell multiplication as made by Dr. Collier are only approximate, but are certainly near enough to the truth to warrant drawing the conclusion that fat is not the result of fatty degeneration of the cells. In fact, such a process is incompatible with our knowledge of the physiology of the cell reproduction or disintegration.

Soxhlet has recently advanced the theory [b] that milk is the result of the disorganization of tissues, either of the milk glands themselves,

[a] New York State Experiment Station Report, 1891.

[b] Journal Royal Agricultural Society, 3d Ser., Vol. III, pp. 655–662.

according to Voit, or of the white blood corpuscle, according to Rauber. Thus, according to Soxhlet the constituents of food can not be directly converted into components of milk, but must first be used for the construction of some tissue and afterwards be decomposed and then utilized in the production of milk fat. A normal butter fat could then be produced by food devoid of fat, and feeding any kind of food devoid of fat, although rich in fat-forming constituents, would not have the effect of changing the character of the milk fat present in milk. Abundant feeding with nutritive but nonfatty foods could only increase the percentage of decomposing milk tissue. Carbohydrates could contribute to the body fat, but not to the milk fat, because they contribute nothing to the milk-producing tissues; but, on the contrary, when fed in conjunction with food poor in protein they diminish the milk fat because the total diminishes the amount of nitrogenous food—that is, substances which produce tissue. It is only fat in food which renders the exclusive increase of milk fat possible by causing a migration of body fat to the milk.

A close examination of the theory, and the explanation given by Soxhlet, shows that it explains many phenomena that could not be explained by the transudation of cell disintegration theories. It must be admitted, however, that it ignores any special constructive power in the gland itself and treats milk as an excretory product.

The latest theory is to regard milk as a product of metabolism of the cells of the mammary gland. It is in all essential characters a secretory product. In viewing the physiology of the formation of milk in such a light, it is only regarding it in the same way as saliva and gastric and pancreatic juices. It may be argued that these glands secrete a special product to be used in the animal economy, while milk is not so used. All excretory glands, as the kidneys, liver, and sweat glands, find their material already prepared in the blood, the result of activity in other parts of the body, and they serve as a means of eliminating it. Secretory glands, as the pancreas, salivary glands, etc., do not find their active principles in the blood, but construct them within their own special cells. The mammary gland does not find fat, casein, and lactose in the blood, but constructs them within its own tissues. The recognition of the mammary gland as an organ having a special function will explain fully all the difficulties met in trying to reconcile all other theories with the facts as they are observed.

The theory of special cell metabolism is supported by the behavior of the gland viewed from an anatomical standpoint. The cells differ when at rest and when active. When at rest the cells lining the alveoli lie flat and close to the wall. Their nuclei are small and spindle form. During a period of activity they are much enlarged, filling nearly the entire cavity, and the nuclei are prominent. The cells may

be seen in all stages of reproduction, and in these particulars the gland shows the same characters as seen in the secreting glands already mentioned.

This theory is further sustained by the antecedents of the milk. When fat is taken into the intestine and assimilated it no longer has an existence as fat, but is broken up into various combinations. Fat as deposited in the body is not the same as the fat in the food. The proportions of olein and stearin have been changed to meet the peculiarity of the animal. Where the analytic and synthetic processes take place is not known. It is now recognized that it is not necessary that the fat in the body be derived from the fat of the food, but that the carbohydrates supply the necessary materials. With these proofs of synthetic process going on to produce body fat, it is not unreasonable to suppose that a similar process may take place in the formation of milk.

The milk sugar, or lactose, is a product of metabolic activity of the protoplasm of the secreting cells of the mammary gland. This particular form of sugar occurs nowhere else in the body. It is a typical carbohydrate, and is found in the milk of animals fed exclusively upon meat, thus showing that the carbohydrates of the food are wholly unnecessary. Of all the constituents, the milk sugar is least affected by external conditions.

The casein of milk is thought to be formed the same as the fat, although authorities differ on this point. The evidence seems to be in favor of this theory, for at the beginning and at the end of lactation the albumin, which is normally less than one-seventh of the casein, is actually in excess of it, and albumin is a normal constituent of both blood and milk. Smith says casein is developed at the expense of the albuminous cell contents, since it is absent from the blood. The alkali albuminate is derived from the breaking down of the protoplasm and nuclein, which is always found as a part of the casein and is derived from the nucleus which disappears in the process of secretion. The proportion of casein in the milk is increased by greater perfection in the activity of the cells. In the formation of colostrum, the albuminoid matter is greatly in excess of that after secretion is well established, and with the decrease of albumin there is a proportionate increase in casein. A ferment has been extracted from the mammary gland which will convert albumin into casein.

The water, no doubt, passes directly from the capillaries into the milk follicles, and carries with it the mineral constituents in solution.

The functions of the mammary gland are performed involuntarily. There seems to be some connection between the mammary gland and the central nervous system, but how much control can be exercised by will has not been determined. Locally the stimulus seems to be

the empty milk duct, for when the ducts become full the secretion is partially checked, but is considerably stimulated during the process of milking.

INFLUENCES AFFECTING MILK PRODUCTION.

Breed.—Heredity has a most marked effect upon milk production. The different breeds are the result of the selection of animals of certain types, and some have been selected to produce very rich milk, others large quantities of milk, and with others no attention has been paid to these qualities. The difference in the quality of milk due to breed includes not only the amount of fat, the color and melting point of the fat, but also the size of the milk globules. In some breeds the globules are large, in some they are small, and in some they may be mixed—large and small. While the breed has a most marked influence, there is also considerable variation of the individuals in each breed.

No figures are available that give a good index to the amount of milk and the period of lactation in the different breeds of cattle in this country. The only animals of which we have record are individuals, mainly owned by experiment stations or in breeding establishments, which are of more than average quality.

Heredity.—As a breed represents only the characters of individuals fixed by selection for successive generations, it is but natural that we should find like influences in families, but in a less marked degree. Heredity has its effect in stamping individuality, both in the quantity and quality, and no stronger proof is needed than the records of the noted families of the breeds.

Age.—Age will influence the quantity of milk. From 2 until 5 years there is a gradual increase in the quantity, after which time it remains about the same during the periods of activity, until the age of 11 or 12 years, and then it decreases.

Pregnancy.—Pregnancy always has the effect of decreasing the flow, first due to a tendency of the body to take on flesh for a time after conception, and in a later period the nutrition is utilized for the fetus. It is in respect of the period of lactation that individuals show the widest variation. With many the effect of again becoming pregnant is so slight as to be scarcely noticeable, and with others it is so great as to interfere with the usefulness of the animal.

THE INFLUENCE OF FOOD UPON MILK SECRETION.

During the period when physiologists attempted to explain practically all changes upon chemical and physical bases, the teaching was that milk resulted from a separation of its constituent elements from

the blood, the separation taking place in the udder. Upon this teaching the belief became fixed that the quantity and quality of the milk secretion was in a measure dependent upon the amount and kind of food the animals received. The influence of this teaching is still potent. Many elaborately planned experiments have been made by individuals and experiment stations to determine the truth or falsity of this view. The results have been very confusing, unless all the data be known. It must be admitted that a large percentage of practical dairymen believe they can take poor or average cows and by good feed and management greatly increase the quantity and better the quality of the milk produced. The results at experiment stations have not been wholly in accord with this view. No doubt the dairyman taking a cow in poor condition, scarcely receiving sufficient food to maintain the body nutrition, and giving her good care and abundant feed, will be able to increase both the yield and quality. The experiment station or person who takes an animal in a good state of nutrition and feeds highly may still further increase the flow or maintain it, and may improve the quality for a short time, but not permanently. The error too often committed by the dairyman in drawing a proper conclusion is, first, testing the milk for quantity and quality which is below the normal for the animal because of her impoverished condition, and, second, in drawing the conclusions from the temporary change occurring soon after the change in food. The experiment stations, as a rule, use only well-nourished cattle, and consequently do not find such marked changes, and furthermore they keep the records for a longer period of time, so that the conclusions are not biased by the incomplete data obtained from the temporary changes. Among those who believe that the quality of milk is practically a fixed character in any given individual and not subject to more than temporary variation by the feeding are G. H. Whitcher and S. M. Babcock.[a] The latter sums up the matter as follows: "My opinion is that the quality of milk, so far as it is measured by the percentage of fat, depends almost entirely upon individual peculiarities of the animal, and so long as sufficient food is supplied and consumed, very little depends upon the kind of food. External conditions, which often are not apparent, seem to have a greater influence upon the richness of milk than the kind of feed. This is shown by the fact that the daily variations in the percentage of fat in the milk from the same cow, when no change has been made in the ration, are often greater than occur when a radical change in the food is made." Furthermore, the same ration will affect different animals differently. According to this theory, the man who endeavors to keep up the

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[a] Rural New Yorker, July 15, 1891.

standard of his milk by careful feeding can not attain that end, and has no advantage over his neighbor who uses the cheapest ration possible.

According to other writers, as Youatt[a] and Wing,[b] the food has considerable influence upon the quality, but not to the same extent as the quantity. In fact, with cows kept under favorable conditions, with an abundant supply of food, it is hardly possible to increase the proportion of fat to other solids by a change in the food. While the total solids can not be easily affected, the character of the constituents may be influenced, and this is notably so of the fat. For example, linseed meal, gluten meal, and certain other foods make a soft, oily fat, while cotton-seed meal, the seeds of the various legumes, and wheat bran make a hard fat. The constituents other than fat are not so easily affected. When cows are fed on watery herbage, brewers' grains, or other food containing a high percentage of water, the milk becomes poorer in solids. The explanation offered for this last condition is based on the assumption of a more watery character of the blood, due to the excess of water in the food. A poor, watery diet impoverishes the blood and leads to the production of watery milk.

The assumption of a watery diet producing a watery milk is not fully in accord with close observation, as it has been found that the fat content is not diminished by turning cattle from dry feed to pasture. It is in line, however, with the statements so frequently accredited to health boards, that cattle fed on brewers' grains and starch refuse have a lower fat content in the milk than those using dry feeds. My own analyses do not show sufficient difference to be able to decide from the milk test alone which dairy uses sloppy feed and which has dry feed and pasture. The average of a large number of analyses from dairies using slop feed shows about one-half of 1 per cent less fat than dairies using dry feed and pasture. No factor other than food seems to account for the difference.

TIME AND OTHER CONDITIONS ESSENTIAL IN FEEDING EXPERIMENTS.

Typical experiments to determine the effect of food upon the quantity and quality of milk seem to show that some foods have more effect upon milk production than others. In all cases the influence is within narrow limits and can all be accounted for probably by the general effect upon the body, or by one food being more palatable than another and therefore more agreeable to the animal. The effect upon milk is probably no greater than it is upon the body as a whole.

The discrepancy between the results obtained by different experi-

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[a] Complete Grazier, 1893.

[b] Milk and its Products, 1897.

menters may often be accounted for by the difference in the method of conducting the experiments. The usual length of time given to each period in a feeding experiment is ten days or two weeks. Many foods have a temporary stimulating effect which naturally shows in such short-period experiments and which would disappear if the period were continued for a longer time.

The duration of the period that should be given to an experiment was also studied at the Vermont Experiment Station. The results there show that the period should be about four weeks in order to make a comparison of quantity and that the period should be six weeks or more in order to get a comparison in quality. This is another evidence of the slow rate at which physiological changes take place in an organ having a fixed habit and also the folly of drawing conclusions from short experiments upon animals.

EFFECTS OF CERTAIN FOODS AND DRUGS.[a]

A great many substances may be transmitted to the milk. The volatile fats that are derived directly from the food may give either desirable or undesirable flavors to the milk. The characteristic flavors we esteem are due to the grasses, clover, and like fodders, while the undesirable are due to leek, garlic, onions, turnips, cabbages, fish, etc. We also find poisonous substances, such as camphor, turpentine, camomile, aloes, arsenic, lead, and tartaric acid, transmitted to the milk. Milk to which aloes, mercury, and copper have been transmitted frequently is injurious. If proper precaution is taken, the undesirable flavors and detrimental effects may be easily obviated, since all these flavoring oils pass off through the excretory channels in a comparatively short time. We shall find them present in the greatest amount, not only in the milk, but in all the tissues of the animal during the time the fodder containing them is undergoing digestion, and by the time digestion is completed the volatile products will have almost entirely passed away. Thus, if care is taken in feeding, so that it will be performed at least eight to ten hours before milking, there will be slight danger of contaminating it. If milking should occur in four or five hours the milk will have an undesirable flavor. Taking advantage of this and feeding the cow immediately before or after, dairymen are often enabled to feed large quantities of turnips and even onions without contamination of the milk. The presence of wild garlic and wild onions in the pasture is a source of bad flavor to the milk. Of course, the remedy here is to remove the wild garlic and onions. It is claimed that placing a small piece of saltpeter in the milking pail will counteract the odor of the turnips. A peck of onions fed to a cow will impart no more odor to the milk than will a

[a] Experiment Station Record, Vol. V; p. 973.

small piece of onion added to the milk. Vandenhoydouch[a] reports a case in which milk of all the cows of a village became bitter, although the cows were healthy. The cows were fed on Swedish turnips which had been washed in foul ditch water. As soon as this was discovered and remedied the milk became all right. Weigmann and Zurn report a case in which the straw used for bedding caused soapy milk. E. Hess, J. Schaffer, and H. Lang have observed the effects of Glauber's salts[a] on some of the cattle of Switzerland. They fed 4 cows, increasing from 40 to 60 grains per head daily, and compared the results with common salt. The cows gave signs of disease of the udder, such as bloody milk, caking, and catarrh. After four days the milk was again normal, but had a taste similar to a weak solution of Glauber's salts. The most striking change in the milk was a decrease in the ability of the casein to be curdled in rennet. The effect of feeding potassium chlorate, according to Bieler, was an increase in the yield of milk at the expense of quality. Cornevin found that pilocarpin increased the sugar from about 0.65 of a gram to 5.5 grams per liter.

Soxhlet[b] has succeeded in demonstrating that butter made from cows fed oil has a melting point of 10° F. higher than normal butter.

EFFECT OF WATER.

There is a popular notion that the more water that a cow can be induced to take into the system the more milk she will yield. To prove this, animals were fed silage two periods, with corn fodder between, and succeeding which corn fodder with silage was used. In every case where there had been a decrease in milk flow there had been a decrease in total amount of water taken into the system, and in every case where there had been a gain in the milk there had been an increase in the amount of water taken into the system. Three cows drank for both silage periods 2,182 pounds of water, and both fodder periods 2,849 pounds of water, but the silage eaten contained 2,489 pounds of water, so that the total water taken during the silage period was 6,226 pounds, while for the fodder period only 5,435 pounds of water. For the silage periods the cows gave 19.07 pounds of milk daily, and the fodder periods 18.51 pounds, showing that during the period in which the greatest quantity of water was taken into the system they gave the most milk in return. It is also shown that as the period of lactation advances, the amount of decrease of water taken into the system and the amount of milk produced are almost exactly in the same proportion; that is, the decrease of water taken in

[a] Experiment Station Record, Vol. V, p. 971.
[b] Journal Royal Agricultural Society, 3d Ser., Vol. III, pp. 655–662.

during the second silage period was 19 per cent of the amount in the first, while the milk decreased 20 per cent.

In the fodder period, the second shows a decrease of 14 per cent of water and 13 per cent of milk over the first period, while in all the periods the decrease of 14 per cent of water and 13 per cent of milk occurred from the first.

That this is not chance, but characteristic of cows, will appear from a study of the experiment made during three years at the Wisconsin Experiment Station.[a] In seven out of eight tests the cows took more water into the system daily and gave more milk while feeding on silage than on corn fodder, and in the other cases the amounts were equal, thus showing that the rations which produced the most milk contained the most water. When silage was fed with water at 39° F. there were 2.9 pounds of water drank for each pound of milk yielded.

Two experiments were conducted at the Wisconsin Experiment Station to ascertain the effect of the temperature of the water on the milk production. One experiment lasted for sixty-four days and the other one for sixty days. There were six cows used in each test. One lot was given water at a temperature of 32° F., and the other at 70° F. In the first experiment the time was divided into three periods of sixteen days each, with intervals between them. At the close of these periods the water temperatures were reversed—that is, the cows which received water at 32° F. were given water at 70° F., and vice versa. The warm water gave the best results, making 1.002 pounds more of milk per day. The cows ate more while on warm water than on the cold. The fat content was about the same in the samples of the different milk.

It is an interesting fact that a cow in full flow of milk requires from one-fourth to one-third more water than when she is not giving milk, and a cow giving a large quantity of milk requires more than one not giving so much. Cows not giving milk require from 70 to 80 pounds daily upon dry feed, and from 100 to 120 pounds daily when giving milk.

THE EFFECT OF CHANGE IN TEMPERATURE AND STORMS.

The effect of sudden change in temperature seems to affect the secretion of milk in an indirect manner through the nervous system. It would be but natural to expect that some effect would be noticed either upon the quantity or quality or both. An examination of the milk in butter-fat record of the cow Early Morn at the Indiana Station for one year fails to show any connection between the quantity and

[a] Wisconsin Agricultural Experiment Station, Bul. No. 21, and Reports 1889-1890.

quality of her milk and the condition of the weather. In fact, her greatest variations occurred at times when the weather was stationary. It may be remarked in this case that this might be due in part to the unusual good protection which she received.

The study made upon the effect of temperature at the Vermont Experiment Station and its results seem to show that the effect of temperature upon the quality of milk is an inverse one, that almost two-thirds, or exactly 61 per cent, of the changes in quality were in opposite directions to the changes in temperature. During the period under observation there were 31 changes of temperature—17 rising, 10 falling, 4 stationary. On fifteen of the days, when the weather became warmer, the fat in the milk decreased, and as the weather became cooler the fat increased. The tendency of this would seem to be that the milk became richer when the temperature was falling and less rich during the rising temperature. In the test in 1892 there were 55 chances for comparing the effect of changing temperature upon the percentage of fat in milk, and 33 to test the effect on the percentage of total solids. There were 22 cases of rising, 21 of falling, and 12 of stationary noon temperature. During the twenty-one days the fat percentage in night's milk changed in opposite direction to the temperature, during eighteen it changed in the same direction, and in four cases there was no change in fat percentage, thus confirming the former test. The total solids were found to rise and fall in much the same way as the fat. During the thirty-three days of the first half of the test, in which the calculations of the solids were made, there were fourteen days of rising, twelve of falling, and seven of stationary noon temperature. On fifteen days the percentage of total solids in the night milk varied inversely, on seven days the changes were in the same direction, and there were four cases of no change. A little more than two-thirds (68 per cent) of the changes were in the opposite direction to the temperature changes. In the experiments the changes in the inverse direction were more decided than those in the same direction.

During the test made in 1891 by the Vermont Experiment Station [a] there were several heavy storms. The amount of milk delivered immediately following these was larger than just before. The quality of milk can not be said to vary much in any direction, but the milk of the second morning after the storm was less in quantity and richer in quality than before. The amount of this disturbance was not in accord with the severity of the storm. The cows do not appear to have made any change in the quantity or quality of the milk on the approach of the storm, and no connection is traceable between the storms and pounds of butter produced.

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[a] Vermont Agricultural Experiment Station, Report 1891.

Observations after 60 storms show that after 7 there was diminished quantity and after 3 there was no change.[a]

In experiments conducted at this station (Indiana) in 1893, milch cows exposed to the weather in the winter, but provided with night shelter, made a very unfavorable showing as compared with those given shelter in the stable excepting for brief airing when the weather was suitable. The exposed cows ate more food, lost in weight, and also in milk yield, while the sheltered ones gained in weight and made a better showing. At the Kansas Experiment Station similar results were obtained.

REGULARITY AND UNIFORMITY OF MILKING.

While the process of milk secretion is a continuous one, it is not entirely uniform, for, as is generally believed, the rate of secretion is increased greatly while milking. Again, in proof of this the distention of the milk ducts and reservoirs by milk already present acts as a check upon secretion. In all cases the udder becomes unduly distended with milk between milkings, and an increased flow will be secured by milking off the milk. The time of milking should be regular, for a difference of an hour will frequently make a difference of 10 per cent in the amount secreted, and if the irregularities are frequent a diminished flow will result. The amount given is also considerably affected by the way in which the milk is drawn. In general, it may be said that rapid milking is conducive to a large flow. At all times the milk should be drawn so that no discomfort is caused to the animal, and in this respect there is a great difference among milkers. A rapid, uniform stroke, with a firm touch of the teat and a stroking motion of the lower part of the udder gives the best results. Babcock has found that certain milkers get not only more milk than others from the same cow but that it is richer.

The Vermont Experiment Station undertook to demonstrate[b] the fact that fast milking is more advantageous than slow. In so doing, 8 cows were used in the experiment—4 full milkers and 4 strippers. The slow milking took more than twice as long as the rapid milking. The experiment proved two things: First, the diminution in the milk flow from one period to another; second, essentially unchanged quality. All the cows gave less when milked slowly, although in three cases the difference was but slight.

Two cows milked every hour for seventy-two hours gained both in quantity and percentage of fat. The gain the first day was much greater than afterwards.[c]

[a] Bul. No. 30, Nebraska Agr. Exp. Station, C. L. Ingersoll and H. B. Duncanson.

[b] Vermont Experiment Station, Report of 1891, p. 55.

[c] Bul. No. 9, New Hampshire Agr. Exp. Sta., G. H. Whitcher.

H. H. Dean tried milking diagonal teats[a] to see if there would be an increase in the milk production. With one cow there was no difference; with another, less milk was given. F. Albert tried a similar experiment and found that by milking the quarters or diagonal teats there was a marked increase in the quantity. He was so sure of his conclusions that he strongly recommends that this method of milking be always followed.

Dr. E. L. Sturtevant had the different quarters of the udder of a cow milked separately a number of times and the milk weighed and the total solids and fat determined. He found a marked difference in the quality of the milk from different quarters of the udder. Dr. Babcock made a similar experiment along the same lines and reported that, for any single milking, the results fully confirmed those of Dr. Sturtevant and showed a decided difference in the quality of the milk from different teats. If, however, the whole series be considered, it is evident that the order in which the teats are milked is the chief factor which affects the quality of the milk. Dr. Babcock says in conclusion: "It is doubtful about there being any difference in the physiological function of the different quarters of the udder." At the Indiana Experiment Station like experiments were conducted with the same results. At the North Carolina Station cows milked one teat at a time showed a less percentage of fat than those milked as usual.[b]

EFFECT OF EXERCISE.

Though locomotion is detrimental to the yield of milk, it is a mistake to suppose that uninterrupted confinement in the stall is the most economical treatment for a milch cow. With moderate locomotive exercise the slight reduction in quantity of milk appears to be fully compensated by the increased yield of solids. Munk undertook to settle this point, and experimented with 30 cows and found that when they were allowed half an hour daily exercise the total quantity of the milk, as well as the fat and casein, increased, though much exercise exerted an adverse influence on the yield. When cows are on grass their increased appetites in the presence of an abundance of food quite makes up for any loss incurred in the movement necessary to obtain that food. Hence it is desirable that stall-fed milch cows should have daily exercise. Very violent exercise sometimes has the effect of producing very much change in the quality as well as the quantity. It always has the effect of lessening the quantity, but the effect upon chemical composition is not known. There are numerous instances, however, in which the physiological effect of taking milk

[a] Experiment Station Record, Vol. V, p. 965.

[b] Bul. No. 116, North Carolina Agr. Exp. Sta., F. E. Emery.

from an exhausted animal has proven injurious. It is generally recognized among farmers that it is unsafe to allow a calf or colt to suckle when the dam is overheated.

EFFECT OF CHANGE OF LOCATION.

The effect of a change of quarters on the quantity and quality of milk was experimented upon by the Vermont Station. The herd was milked, and then driven 3½ miles to new quarters. Composite samples were taken of the milk of 7 cows for 4 milkings before and after the change. Six and one-tenth per cent larger yields of milk ingredients followed the change. Babcock found in a similar experiment a falling off in both quantity and quality, but the increase of the succeeding days more than compensated for the decrease. A change in the stable routine, as feeding out of order or at irregular times, may have like effect.[a]

EFFECT OF NERVOUSNESS.

Both the secretion and the excretion of the milk are under the control of the nervous system, but the exact mode whereby the nervous influence is exerted remains to be worked out. Indirectly, however, the secretion of milk must largely be affected through the sympathetic nervous system, whose center is a chain of nervous element extending along the general body cavity just beneath the backbone. The nerves act by controlling the caliber of the blood vessels, and thus regulating the blood going to the udder. It is a well-established fact that anxiety of the mother, caused by removal of the young, as well as by sudden fear—all chance excitement of any kind—will cause a partial and sometimes a complete suppression of the milk secretion. Not only is the amount of milk secreted affected by the nervous state of the animal, but its composition is also changed, even when the quantity remains the same. Unkind treatment of the cow, willful or otherwise, is found to show its effects in diminishing the yields of milk. Ill ventilated, badly drained, or too drafty cow houses, careless exposure in bad weather, irregular feeding, brutal usage, fast driving, the mad rushing about provoked by the attacks of the ox warble fly, and a variety of other causes are bound to exert an influence upon the nerves, the effect of which will be certainly recorded in the milk pail. At the Vermont Station[b] a test was made of dairy cows at home and at the fair ground to determine the effect of the nervous excitement on the milk flow. The results indicate that the tendency of nervous excitement is to lessen the quantity of milk and variously to affect the quality, according to the individuality

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[a] Bul. No. 116, North Carolina Exp. Sta., F. E. Emery.

[b] Vermont Experiment Station, Report 1895.

of the animal, the fat being the most variable ingredient. In general, the activity of the animal and the nervous excitement decreases the flow of milk, stall-fed animals producing more than grazing animals.[a]

EFFECT OF RAGE, FRIGHT, AND SUDDEN SHOCKS.

On August 12, 1892, at Lake City, Fla., the following case occurred: A fine cow owned by Mrs. T. had a healthy calf four days old at her side. The cow was of a very nervous temperament, and particularly averse to dogs. Upon the night of that date a dog strayed into the stall next to the cow and calf. The cow made frantic efforts to get at the dog, and was in a state of excitement for six hours. The calf remained quiet and unharmed and suckled soon after the dog went away. Three days after the calf died.

Another case occurred August 10, 1891, at Bourbon, Ind. A valuable mare was owned by Mr. C. She had a foal six weeks old. The day was very hot, and the mare was used at the harrow and the colt left in the shade. The mare fretted greatly and was worked a couple of hours longer than usual to finish a piece of work. The foal was allowed to suckle as soon as work was stopped. It died in about four hours. No cause could be assigned except the possibility of the milk having become altered both by fretting and heat.

It has also been observed that after sheep have been frightened or worried by dogs a number of lambs may die which have in no way been disturbed or injured by the dogs. In such cases the milk has seemed to be the cause of the trouble.

[a] There are numerous authentic records of a marked decrease in the percentage of fat as the result of nervous excitement.—H. E. A.

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